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The Use of Chemicals to Control Inferior Trees in the Management of Loblolly Pine

by

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FOREWORD

During the past 5 years the Southeastern Forest Experiment Station has been investigating the behavior and control of inferior trees in the management of loblolly pine. The ecological problems and possible methods of solution were discussed in Technical Note 72, released by this Station in April 1949, "The behavior and control of understory hardwoods in loblolly pine stands," by L. E. Chaiken. It was pointed out in that publication that weed trees could be controlled by prescribed fire, by mechanical methods, by chemicals, and by hand tools. But it was also clearly stated that not a single one of these could be considered a cure-all by the forester harassed with "brush."

The investigations reported in Technical Note 72 have been continued, with particular emphasis upon the use of chemicals. Now, on the basis of records of more than 10,000 treated trees, we can evaluate the usefulness of chemical control. In doing so, we are fully aware that the final word has not been written, but what we have learned during the past 5 years, and what we think it means, is reported here.

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THE USE OF CHEMICALS TO CONTROL INFERIOR TREES IN THE MANAGEMENT OF LOBLOLLY PINE

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A sales executive of a large chemical company once predicted that the use of chemical weed killers would eventually be greater for the control of brush and woody plants than for the control of weeds in agricultural crops. That was four or five years ago when only scattered tests were being made of the newer herbicides to determine the possibilities of controlling woody species. The sales executive will be pleased if his prediction comes true, but the forester cannot help being impressed by the tremendous increase in the use of these chemicals. For example, it is estimated by Stahler (7) that over a million acres of mesquite will be chemically controlled during 1951 on the Texas ranges. And over the country hundreds of thousands of miles of rights-of-way have been treated for the control of brush and tree sprouts.

What use can foresters make of the chemicals? Or, more specifically, as far as this publication is concerned, how can these chemicals aid in the management of loblolly pine in the Carolinas? Let's look at the problems. In common with all other timber-producing forest types throughout the country, our sole silvicultural objective is to sustain well-stocked stands of valuable tree species adapted to the site. Like many other forest types, much of our forest land is occupied by inferior trees. Obviously, any space on the forest acre occupied by trees of inferior species or quality is just so much space unavailable to trees of higher value.

In the loblolly pine region of the Carolinas, the problem of aggressive hardwood weed species is particularly acute. During the past two decades there has been a steady building up of dense undergrowths, mainly of sweetgum, with local associations of blackgum, oaks, southern waxmyrtle, gallberry, and hickories. Their growth rate is accelerated

when they are released by the removal of part or all of the pine overstory, and competition with the pine reproduction becomes quite severe. On many sites there is a very definite type conversion--from pure pine to pine-hardwoods mixtures, and eventually, perhaps, to almost pure hardwoods.

There are two ways that a forester can meet this problem. First, he can provide more pine seed and better conditions for germination. And second, he can physically subordinate or remove the inferior trees. In either case he attempts to achieve the purpose of increasing the pine component. Practically, however, he often has to do both.

Methods of increasing the loblolly pine seed supply and improving the seedbed are currently being studied, and progress reports have been issued by Pomeroy (6) and Trousdell (8). Decreasing the hardwood component by prescribed fire, by mechanical methods, by chemicals, and by hand tools has been reported by Chaiken (2) and others.

Tree poisoning is not a new notion.--At least 25 years ago, studies were made of the use of arsenicals, principally sodium arsenite. Since then many chemicals have been tried, with varying success. Among these were: sodium and calcium chlorate; potassium chromate and bichromate; copper and iron sulphate; copper, sodium, barium, and zinc chloride; ammonium thiocyanate; formaldehyde; carbolic acid; sodium fluoride; ethyelene oxide; cresylic acid; kerosene; creosote; and many others (1). None, however, was entirely satisfactory, either because of ineffectiveness, toxicity to the user, or because of high cost. Interest lagged in the use of tree poisons until the end of World War II, when a number of newly developed chemicals came into use. Undoubtedly the reawakening of interest has been stimulated by the remarkable success of these chemicals as selective herbicides. In any event, foresters began to ask, "What are these chemicals and what can they do for us?"

THE CHEMICALS

Ammonium sulfamate (much better known by its trade name "Ammate") was for many years considered an interesting but useless product until its herbicidal properties were discovered about 10 years ago. Ammate is generally used in its dry crystalline form or as a water solution, and occasionally emulsified with oil. It is non-toxic to humans, wildlife or livestock but may cause minor skin irritation under prolonged contact. Its residual effect as a soil sterilant is negligible for forest uses. However, Ammate is quite corrosive to ordinary metal containers, so that stainless steel or protectively coated equipment should be used.

2,4-Dichlorophenoxyacetic acid and 2,4,5-Trichlorophenoxyacetic acid (simply abbreviated as 2,4-D and 2,4,5-T, respectively) are related plant hormone compounds now widely known, especially the former, for their ability to kill weeds. The acids themselves are seldom, if ever, used as weed killers--rather they are formulated as metallic salts, amine salts, and esters. Although there are many of these to choose from, the forester need not be troubled in making a selection. The low volatile esters of these chemicals, such as the butoxy ethanol or the propylene glycol butyl ether ester, have thus far proved to be more effective in the control of inferior tree species in the Carolinas than any of the other formulations we have tested. Therefore, unless otherwise specified, future reference to 2,4-D or 2,4.5-T in this publication will mean these low-volatile esters.

Neither 2,4-D or 2,4,5-T is harmful to the user or to wildlife and livestock. They are also non-corrosive, which gives them some advantage over Ammate. And like Ammate they have little residual effect as soil sterilants. Preparations of 2,4-D and 2,4,5-T are marketed as liquid concentrates that are diluted before use. The diluents, or carriers, may be either water or such petroleum oils as kerosene, fuel oil, or diesel oil, depending upon the use that is made.

Other chemicals are used as silvicides. Sodium arsenite, for example, is one of our most effective tree poisons, but it is hazardous to use. It has given excellent control of many tree species, such as

bitter pecan in the Mississippi Delta (4). Both in Canada and this country, sodium arsenite is coming into greater use to serve the double purpose of killing trees and making their bark easy to peel. Yet the forester in the Southeast, where stock grazing is frequently uncontrolled, is reluctant to take the risk of using a chemical as highly toxic as sodium arsenite.

Sodium chlorate, polybor chlorate, the dinitros and the trichloroacetates, as well as dozens of other chemicals, even borax and common salt, will injure woody plants. None of these is as widely useful to the forester as Ammate, 2,4-D, and 2,4,5-T.

CONCENTRATION AND DOSAGE

Concentrations of these chemicals are expressed in different ways. Using the water emulsion of one of the low-volatile esters of 2,4,5-T as an example, concentration may be given as: (1) the ratio of the weight of the 2,4,5-T acid equivalent of the 2,4,5-T ester to the combined weight of the water carrier plus acid, expressed as a proportion; e.g., 10,000 parts per million, or (2) the same ratio expressed as a percentage; e.g., 1 percent acid by weight, or (3) the ratio of the volume of the manufactured product or concentrate to the volume of the water carrier, expressed as a percentage; e.g., 2 percent by volume. If the product as marketed contains the equivalent of 4 pounds of 2,4,5-T acid per gallon of 2,4,5-T ester concentrate (as is now common marketing practice), then the three expressions of concentration cited above are equivalent; that is, 10,000 parts per million = 1 percent acid equivalent by weight = 2 percent of the product by volume. The latter expression of concentration is quite simple to understand. A solution of 2 percent 2,4,5-T (by volume) may be prepared by adding 1 gallon of the concentrate to 49 gallons of water (50 gallons of water would be close enough).

Solutions or emulsions of 2,4-D or 2,4,5-T of any desired concentration are easily prepared by following the proportions given in

table 1, if the commercial product or concentrate contains the equivalent of 4 pounds of acid per gallon.

Table 1.--Approximate proportions of commercial product (containing 4 pounds of 2,4-D or 2,4,5-T acid per gallon) required to prepare solutions or emulsions of desired concentrations

Concentration by weight of acid		Concentration by volume of concentrate	Volume of product to make 1 gallon of solution			Volume of carrier to add to 1 gallon of product
(Percent)		(Percent)	(Milliliters)		(Ounces)	(Gallons)
			WATER CARRIER			
1/4	=	1/2	20	=	2/3	200
1/2	=	1	40	=	1-2/3	100
1	=	2	80	=	2-1/2	50
			OIL CARRIER			
1	=	1-2/3	65	=	2	60
2	=	3	125	=	4	30
3	=	5	200	=	6-1/2	20
5	=	8	325	=	10	11
6	=	10	400	=	13	9

Concentrations of Ammate solutions are usually expressed as "pounds of Ammate per gallon of carrier," rather than in terms of the active ingredient, ammonium sulfamate (of which Ammate contains 80 percent).

For agricultural crops a favored expression of concentration, particularly for 2,4-D is "pounds of acid per unit area." More precisely, it is an expression of dosage rather than concentration, and as such gives an accurate statement of the amount of active ingredient applied. The usefulness of this expression becomes apparent when we consider that a given acre can be treated with either 60 gallons of 1-percent (by weight) solution of 2,4-D or with 12 gallons of 5-percent solution. In both cases, 4 pounds of 2,4-D acid have been applied per acre. Since it is the active ingredient that does the weed killing, both dosage and concentration must be known.

For forest crops, however, expressions of dosages are quite difficult to make. In the first place, "pounds of acid per acre" is of little value because of the tremendous variability in the amount of brush or weed trees from acre to acre or from one forest property to another. In the second place, there is the practical difficulty of measuring or even estimating how much chemical solution is being applied if individual trees are being treated. And finally, we know that the amount of active ingredient is not always an index of tree-killing capacity. For example, very light dosages or low volumes of high concentrations will not kill basal-sprayed trees, although a lesser amount of active ingredient applied as a higher dosage will do so. As a consequence, we have resorted to recommending spray dosages in such inexact terms as "to the point of runoff," or "as much as the tree will take."

METHODS OF APPLICATION

These chemicals have been applied to the weed trees or brush in just about every imaginable way: to the foliage, to the bark, on wounds, on stumps, in notches, in frills, and in slits. Any method will work that introduces enough of the toxic material into the conducting tissues of the tree. Some methods, though, use the chemical more efficiently than others, so that a minimum amount need be applied. And some methods are easier and cheaper to perform. Some species react differently to different methods; as an illustration, sweetgum is readily killed by foliage sprays of 2,4,5-T but is slow to respond to basal sprays. Just to be contrary, some of the oaks are easily killed by basal sprays but sprout vigorously after foliage sprays. The choice of method of application further depends upon size of weed trees, number of stems or amount of brush, quantity and size of desirable trees, availability of suitable labor and equipment, and, finally, the aim of management.

For convenience, the methods of application have been grouped as: (1) foliage sprays, (2) cut surface methods, and (3) basal sprays.

Foliage sprays

It is natural that the most extensive use of these chemicals for the control of woody plants has been as foliage sprays, since that method is readily applied to masses of brush. Such area-wise control is usually more economical than stem-by-stem treatment where the stems are small and very numerous. Early in our investigations we found, as others have, that just about all the foliage must be treated in order to kill the root system of any given plant. Because it is inefficient to spray all the foliage of large trees, and also probably ineffective, it has become common practice to first reduce large stems by cutting or fire and then spray the resultant sprouts.

Complete eradication of all brush is seldom accomplished by a single spraying, although several repeated sprayings will eliminate all susceptible species. This is illustrated in figure 1. Here are adjacent plots in a 45-year-old loblolly pine stand. Figure 1A is a view of the untreated plot, showing the typically dense brush-like understory of undesirable hardwoods. A prescribed winter fire followed by a single spraying of the foliage of 1-year-old sprouts killed at least 80 percent of the hardwood root stocks, as illustrated in figure 1B. By spot spraying the survivors during the following two successive years, we eliminated practically all the brush, as in figure 1C.

For forest management purposes, however, complete eradication is not needed--nor, indeed, is it even desired. So, if an adequate pine seed source is available to restock the area promptly, or if planting soon follows the clearance of the brush, the control accomplished by a single foliage spraying should be sufficient. Existing or advance pine reproduction cannot be relied on, because the preparatory fire or mechanical disking will, of course, eliminate pine as well as reduce brush. Even if fire or disking is not used, the present chemicals in our foliage sprays are also toxic to pine reproduction, as well as to brush. This method, then, is useful only when we desire to regenerate even-aged stands.

Figure 1A.--Typical of many in the Carolina flatwoods, this 45-year-old loblolly pine stand has a dense understory of gums, oaks, and other inferior species. Occasional large hardwoods are in the overstory.

Figure 1B.--A single foliage spray will eliminate many of the brush-like hardwoods. This plot is adjacent to that shown in figure 1A.

Figure 1C.--Although such control is not necessary, several repeated foliage sprays will eradicate practically all woody vegetation. Grasses quickly replace the hardwood brush.

2,4,5-T for foliage sprays.--All things considered, we believe that the most efficient foliage spray for the species associated with loblolly pine in the Carolina flatwoods is a water emulsion of 1/4 of 1 percent low-volatile esters of 2,4,5-T (acid equivalent by weight). The emulsion may be prepared, as directed in table 1, by adding one gallon of 4-pound commercial product to 200 gallons of water. One gallon of the emulsion or spraying solution as mixed costs about 6 cents. There are other foliage sprays, and some cheaper too, so our experience with them will be reviewed briefly.

When we first began to investigate foliage sprays some years ago, we examined the cheaper chemicals. Early tests with the ammonium and sodium salts of 2,4-D looked quite promising, but we later found that our good results were directly tied in with season of application. For example, a satisfactory kill of sweetgum and associated species was obtained only when we treated during the midsummer, about the time of the formation of the terminal buds. The amine salts of 2,4-D also gave unreliable results. The esters of 2,4-D were much better than the salts but yet not as effective as 2,4,5-T. Nor were combinations of 2,4-D and 2,4,5-T as effective as equivalent or even lower concentrations of 2,4,5-T alone. Solutions of Ammate at 3/4 to 1 pound per gallon of water have reportedly given results as good as 2,4,5-T and sometimes much better, although at a cost two to three times as high. The greater cost and the corrosive properties of Ammate make it less useful for forest management purposes than 2,4,5-T as foliage sprays. We might add that tests of these chemicals showed that an increase in concentration over the minimum effective concentration did not bring about a corresponding increase in effectiveness of kill.

Spray any time after full leafing.--Until later investigations proved otherwise, most research workers believed that these chemicals were more effective when applied to young succulent foliage. While that may have been so for young seedlings, these chemicals, applied to woody plants with well-established root systems, quickly destroy succulent foliage but fail to kill the roots. Perhaps this is because of the limited leaf

area sprayed or the initial vigor of spring growth, but at any rate we have found that 2,4,5-T gives better root kill if applied after full development of the foliage.

Species susceptibility varies.--The foliage of practically all tree and woody shrub species encountered in the Carolina flatwoods is killed by sprays of Ammate or 2,4,5-T, some species more readily than others. However, defoliation does not mean that the roots are destroyed--some species and some individuals will resprout. It is difficult to list species susceptibility, for there is wide variation within as well as between species. Sweetgum, for example, is usually quite susceptible to foliage sprays of 2,4,5-T but there are areas where resprouting has been greater than anticipated. We do not know why. In general, we can expect little resprouting after foliage sprays of 2,4,5-T on sweetgum, blackgum, southern waxmyrtle, and gallberry. Many oaks will resprout, and these are better controlled with Ammate. A few species, such as catalpa and sweet bay, fortunately less common in loblolly pine, seem to resprout just as vigorously after spraying as after mere cutting of the stems.

Woods spraying requires heavy equipment.--In contrast to the ease of spraying rights-of-way, woods operations are rather cumbersome. From 50 to 150 gallons of solution are required to treat an acre of 1-year-old sprouts, so that a tremendous amount of water will be consumed on large areas. Large capacity tanks are needed to haul this water into the woods and heavy motive equipment is needed to haul the tanks. Even in our level flatwoods areas it is frequently difficult to maneuver heavy equipment.

Foliage spraying by aircraft has been used in the extensive brush and range lands of the West and Southwest, but is poorly adapted to the Southeast. Our forest lands are usually in small blocks, intermingled with farm lands, and the chemicals used in brush control are highly toxic to most agricultural crops. Furthermore, the best time to control brush is before it takes over the forest; that is, when it is still a relatively innocuous understory in pine stands--and not easily sprayed by aircraft. All methods of spraying foliage, and particularly when fog machines and mist sprayers are used, require caution to prevent drift into areas of susceptible farm crops.

Foliage sprays are expensive.--A 6-acre block of quite dense 1-year-old sprouts was sprayed at a cost of $11.62 per acre, broken down as follows:

	Cost per acre
Chemical: 125 gallons of 1/4 of 1% 2,4,5-T at $0.06 per gallon	$ 7.50
Equipment charges: 0.5 hours of pump, tank and tractor operation	2.50
Labor: Tractor operator - 0.5 man-hours at $1.00	.50
Spraymen - 1.5 man-hours at $0.75	1.12
Total cost per acre	$ 11.62

(The above are on-the-job costs only, and do not include overhead, transportation, etc.)

This is a costly operation, although other, less dense areas might be treated for about $8.00 per acre. Yet, if the failure to control the brush results in only a partial pine stand, perhaps the investment is justified. Oddly enough, owners occasionally forget that no amount of brush control will produce seedlings unless pine seed is available.

There are other ways to control brush.--Even though single prescribed fires reduce only the size of the stems of inferior species, and seldom the number, they usually exert sufficient control and encourage the regeneration of loblolly pine. Burning is cheaper than spraying foliage. Both size and number of competing stems can be reduced by some mechanical means, such as disking, at a greater cost than prescribed fire but still cheaper than foliage sprays. Almost complete eradication can be obtained, at a rather considerable cost, by either foliage sprays or some such mechanical clearing, as bulldozing. The forester can get just about as much control as he is willing to pay for.

Cut surface methods

Another way to apply these chemicals is to introduce them into the trees through some sort of cut in the stem, such as notches, frills, and incisions, or on the stumps or stubs of felled trees. Since individual stems are treated, it is easy to see that this procedure is usually not applicable to masses of brush, where there may be thousands of stems per acre. Ordinarily, the cut surface methods are used to liberate existing and desirable but overtopped reproduction. It is often difficult to choose which trees to release and which to deaden. This choice depends upon present and expected local markets, and must rest with the individual forest manager.

Should we girdle or poison?--Over the years many trees have been girdled to liberate desirable reproduction. There have been failures and successes--some trees fail to die after girdling, others persist for a long time before dying, and many trees resprout. Nevertheless, with the exception of certain hard-to-kill species, as beech, sweetgum, and blackgum, girdling has generally been effective. So, if tree poisons are to be used, they must offer something more than mere girdling. Without question, the tree poisons are more effective than girdling. They kill trees more surely and more quickly, with little or no resprouting. But there is some question about comparative costs; some poisoning methods appear to be as cheap, or even cheaper than girdling--others definitely cost more.

Ammate crystals in notches.--During recent years one of the most popular methods of poisoning individual trees has been the use of dry Ammate crystals in notches or cups chopped in the base of the tree, as in figure 2. Peevy (5) recommends that a level tablespoonful (about 1/2 ounce) of Ammate be placed in each notch, and the notches be spaced 6 inches apart from edge to edge. Reports of the failure of this method to kill trees of certain species or at some season of the year appear to be due to inadequate dosage. We have found, in the Carolinas, that an increased dosage of a heaping tablespoonful of Ammate (about 1 to 1-1/2 ounches per notch) will kill the species associated with loblolly pine, and at any season of the year.

Figure 2.--Most tree species can be quickly killed by using Ammate crystals in notches or "cups."

The cost of this method is high, from one-and-a-half to two times the cost of double-hack girdling, but the results are excellent. It gives the quickest kill of more species than any other method and chemical we have tested (with the exception of sodium arsenite, which is not acceptable for general use).

Ammate solution in frills.--As recommended by Peevy, a 19.3-percent solution of Ammate (at 2 pounds per gallon of water) is poured into single-hack girdles or overlapping ax cuts encircling the tree.

The cost is about half that of using crystals in notches, and roughly about the same as the cost of double-hack girdles. However, it is less effective than the notch method, but decidedly more effective than girdling. Some basal sprouts are to be expected and an occasional tree will resprout in the crown, apparently recovering entirely from the effects of the chemical. The southern oaks, with the exception of live oak (Q. virginiana), are readily killed by this method. Beech and hickory are difficult to kill, and sweetgum and blackgum are moderately so.

2,4,5-T in frills.--A variant of the above frill technique, using low concentrations of 2,4,5-T rather than Ammate, offers very good control at a moderate cost. An emulsion of 1 percent 2,4,5-T (by weight) costs a little less than a 2-pound solution of Ammate, so treatment should cost about the same as double-hack girdling. And since 2,4,5-T is not corrosive, fewer problems in supply and treatment are encountered. However, the method does have one possible disadvantage: 2,4,5-T does not kill trees quickly. Some species are deadened within several months; others take a year or more to die. But we have observed absolutely no resprouting from properly treated 2,4,5-T frilled trees. Since this method seems to be one of the most efficient ways to poison large individual trees, some of the details of the technique are given:

A 1-percent emulsion of 2,4,5-T by weight, or its equivalent of 2 percent by volume, is easily prepared, as directed in table 1, by adding 1 gallon of a 4-pound commercial product to 50 gallons of water. The emulsion tends to settle out, and must be thoroughly agitated during preparation and at frequent intervals during use. We add a red dye--one of the concentrated wood stains--to the solution to facilitate distinction between poisoned and non-poisoned trees. This permits frill-chopping and poisoning to be done by different men, one man pouring for two to four choppers. The solution may be carried to the trees in 5-gallon back-pack cans, with gravity flow through a nozzle into the frills. The dosage is important: pour in as much as the frill will take without wasting. Two rapid trips around the tree, or one slow trip, should do the job. The method of pouring is illustrated in figure 3A. Some idea of how much chemical to pour into the frill is given in figure 4. The number

Figure 3A.--Since 2,4,5-T is non-corrosive, it can be poured into frills from ordinary metal containers. Back-pack cans, holding about a half-day's supply, are easily adapted for gravity flow.

Figure 3B.--Red oaks show a characteristic bark proliferation when treated with 2,4,5-T.

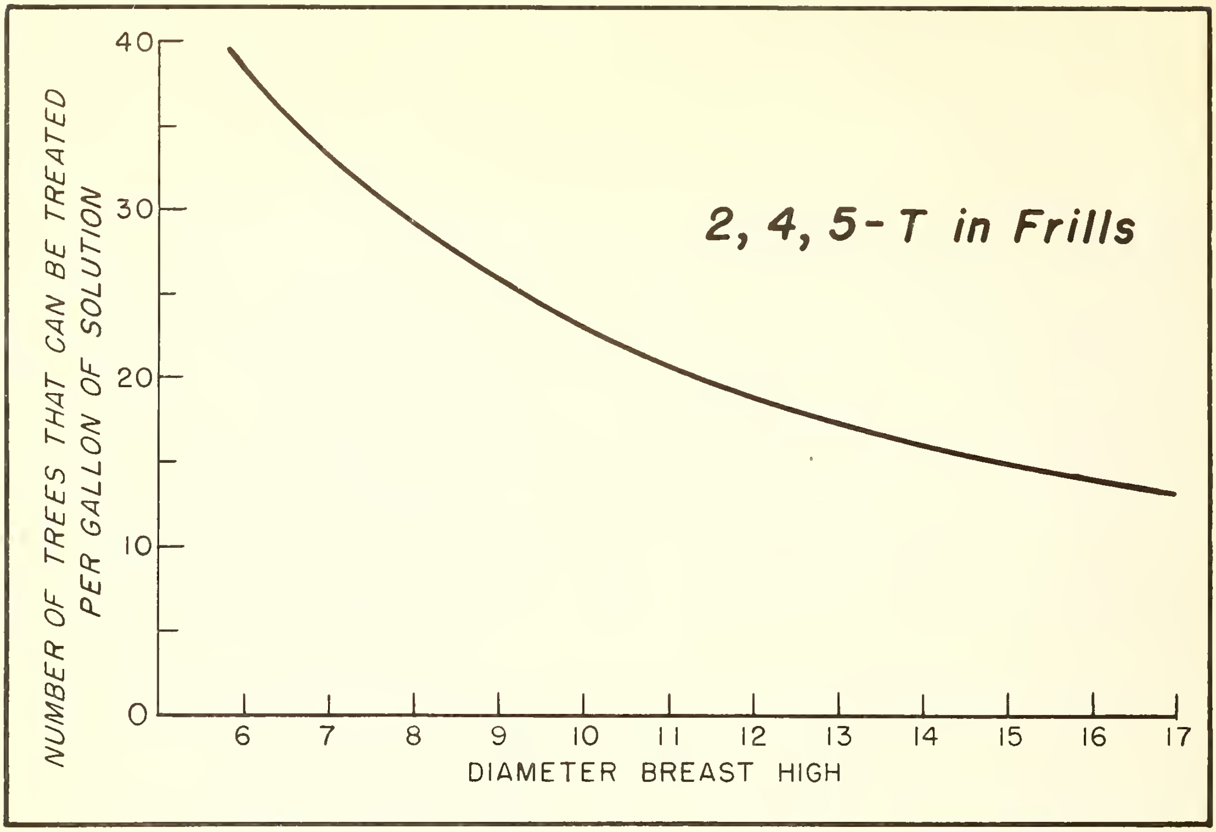

Figure 4.--One gallon of 2,4,5-T frilling solution will treat about 38 trees 6 inches d.b.h. at a chemical cost of 2/3 of a cent per tree, or 13 trees 17 inches d.b.h. at a cost of 2 cents per tree.

of trees that can be treated per gallon of solution varies from 38 trees 6 inches d.b.h. to 13 trees 17 inches d.b.h.

Among the species easily killed by 2,4,5-T in frills are those of the white oak group: live oak, post oak, white oak, and swamp chestnut oak. Some of these, especially live oak, are quite resistant to other tree poisons, and yet we find this species readily killed by even low concentrations of 2,4,5-T. The red oak group ranks next in susceptibility; among these are water, willow, and laurel oaks, and southern red

oak as well as its variety, cherrybark oak. Figure 3B shows the typical proliferation of the bark of red oaks several months after treatment with 2,4,5-T. As with Ammate in frills, beech and hickory are not killed as quickly with 2,4,5-T as are the oaks. Sweetgum and blackgum are slow to respond. However, all species that we have tested can be killed by 2,4,5-T in frills, if treated with adequate concentration and dosage.

The frill method is practical only for trees larger than 4 or 5 inches d.b.h. Smaller trees are difficult to frill properly; these may be poisoned by other methods, or simply felled without poisoning.

If we assume that a gallon of 2,4,5-T frilling solution costs 25.3 cents, we can calculate from figure 4 that the chemical cost per 6-inch tree is about 2/3 of 1 cent, and a little over 1 cent for a 10-inch tree, and almost 2 cents for a 17-inch tree. The time required for frilling and applying the chemical varies with size and spacing of the trees. In several large-scale operations, labor time for frilling, poisoning and walking between trees was 3 to 4 man-hours per 100 trees, averaging 7 to 9 inches d.b.h. Somewhat over 200 trees of this size could be poisoned per man-day of labor in stands averaging 100 trees per acre. Cost figures are less useful here than time requirements, since labor costs depend on local labor rates. However, the examples given below will serve to show how costs were divided among the different phases of the frilling and poisoning operation.

For a 24-acre block the per-acre values are:

Number of trees treated			70
Average d.b.h.			7.6"
Labor			
Chopping,	1.74 man-hours at 75¢	=	$ 1.30
Pouring,	0.58 " " " "	=	.44
Total	2.32 " " " "	=	$ 1.74
Chemical			
1.60 gals. of 1% solution at 25.3¢		=	.40
TOTAL COST PER ACRE			$ 2.14

The above costs represent direct costs only, and do not include overhead, supervision, transportation, equipment, or supply.

In a large test, a pulp and paper company in South Carolina reported the following costs with the use of 2,4,5-T in frills:

	370 difficult acres (per acre)	300 easier acres (per acre)	Percent of total cost
Number trees treated	155	84	
Average d.b.h. (inches)	7.0	9.0	
Labor (man-hours)	5.96	4.68	
Labor (@ 85.8¢ per m.h.)	\$5.98	\$4.02	71
Chemical cost	\$0.76	\$0.54	9
Supervision, transportation, equipment, overhead	\$1.82	\$1.15	20
	\$8.56	\$5.71	100

Relative costs per tree of the frill method and other methods are given in table 2 on page 28.

The poisoning of stumps.--These chemicals have also been used on tree stumps to kill root systems and prevent resprouting. If the sole purpose is to rid the forest property of undesirable trees, there are other and cheaper ways to do it than to fell the tree and poison the stump. But if the undesired tree has a positive stumpage value--even just a few pennies--this method could be used to prevent the regrowth of the inferior species, with part or all the cost of poisoning being offset by the returns from stumpage.

For small trees, below 4 inches d.b.h., a tablespoonful of dry Ammate crystals may be placed on a V-shaped stump. This will prevent the resprouting of many species. It is usually cheaper, especially for larger stumps, to spray the top and sides with an oil solution of 2,4,5-T. A 3-percent solution, by weight (as directed in table 1, 1 gallon of a 4-pound commercial product to 20 gallons of oil carrier) will control most of the troublesome species in the Southeast. An example of the excellent control possible by this method is illustrated by figures 5A and 5B.

Although tests are under way to determine how long after cutting one might wait before poisoning, for the present it is safe practice to treat freshly-cut stumps. The technique requires that the sides as well

Figure 5A.--Stumps may be poisoned to prevent resprouting. Sprayed with 2,4,5-T in oil just after cutting, these sweetgum stumps have not sprouted after two growing seasons.

Figure 5B.--Untreated sweetgum stumps sprout vigorously, as shown by these 2-year-old sprouts, 8 feet tall.

as the top of the stumps be thoroughly wetted, to the point of solution runoff, down to the ground level.

In most deciduous tree species small stumps sprout abundantly, large stumps less so, and very large stumps only infrequently. It is well to be aware of this relationship and spray only those species and sizes that resprout vigorously. An oil-soluble dye added to the spraying solution to stain the stump top will make those treated easily distinguishable for several days.

We have only fragmentary cost data for stump sprays. The chemicals cost about 3 cents for spraying a stump 8 inches in diameter, and labor adds about 1/2 cent more.

Another use for stump sprays is in right-of-way construction. The cost of subsequent maintenance will be considerably reduced if all sprouting species are treated after felling. It is sprouts from stumps with large root systems that give the most trouble in right-of-way maintenance by foliage sprays.

<u>Other cut surface methods</u>.--Foresters trying to find cheaper ways of introducing poisons into trees have used hole-punching tools, combination hacks and sprayers, injection devices, and undoubtedly dozens of others. One of the best, the Cornell Tree Killing Tool, was developed some 20 years ago by Cope and Spaeth (3). Though originally designed for use with sodium arsenite, it has recently been used with 2,4,5-T and Ammate. Our tests using 2,4,5-T are still incomplete, but reports indicate good results with Ammate at 4 to 8 pounds per gallon. The Cornell Tool, or some similar device, may provide the answer to the problem of poisoning many small tree stems, where the cost of labor, rather than the cost of chemicals, has made such poisoning almost prohibitive.

Basal sprays

Alternatively called bark, stem, trunk, or dormant sprays, basal sprays consist simply of spraying a band of bark encircling the base of the tree. The chemicals presumably penetrate the bark, kill the cambium and are translocated downward and kill the roots. The simplicity of the

method, with such little manual labor involved, has captured the fancy of many foresters. Yet, of all the methods of poisoning, this is the most expensive--at least for large trees. Reasons why will be pointed out later.

Although some tree species and sizes may be killed with lower concentrations, we have found most consistent results with 3 percent 2,4,5-T in oil (acid equivalent by weight)--the same as used for stump sprays. The base of the tree must be sprayed up to a height of about 2 feet. For small trees, 1 or 2 inches d.b.h. or less, a band about 12 inches high seems adequate. For any tree, the dosage must be heavy; that is, the solution must be applied until the bark becomes saturated and the excess solution begins to run off. Figure 6 shows the method of application and figure 7 shows the effectiveness of basal sprays.

Most tree and shrub species can be killed by this method. In fact, some species, such as beech and hickory, are more easily deadened by basal sprays than by either frills or notches. It would seem logical that the thin-bark species are more susceptible to this technique, and indeed we find that, in addition to beech and hickory, other thin-bark species, such as hornbeam and southern waxmyrtle, are quickly killed. Among the thicker-bark trees, the white oak group is particularly susceptible. The red oaks can also be controlled. However, sweetgum and blackgum are slow to respond, and variable results are obtained unless quite heavy dosages are used.

Some idea of how much chemical is required to treat individual trees is given in figure 8. One gallon of 3-percent solution will treat about 14 trees 6 inches d.b.h. or three trees 17 inches d.b.h. Remember that a gallon of solution, if poured into frills, will treat about three times as many trees. This is only one of the reasons why basal sprays are more costly than frills. Others are: about two-and-one-half times as much 2,4,5-T concentrate is required to make a 3-percent basal spray solution as is used in a 1-percent frilling solution; the oil diluent used for basal sprays costs about 15 cents per gallon, while the water carrier of the frilling solution costs nothing. Add them up and we find

Figure 6.--A pressure back-pack pump is a handy gadget for basal spraying, but only about four such trees can be treated per gallon of 2,4,5-T solution. The same equipment can be used for stump spraying.

Figure 7.--Beech (A), hickory (B), and elm (C) are usually difficult to deaden; however, these species are readily killed by 2,4,5-T basal sprays.

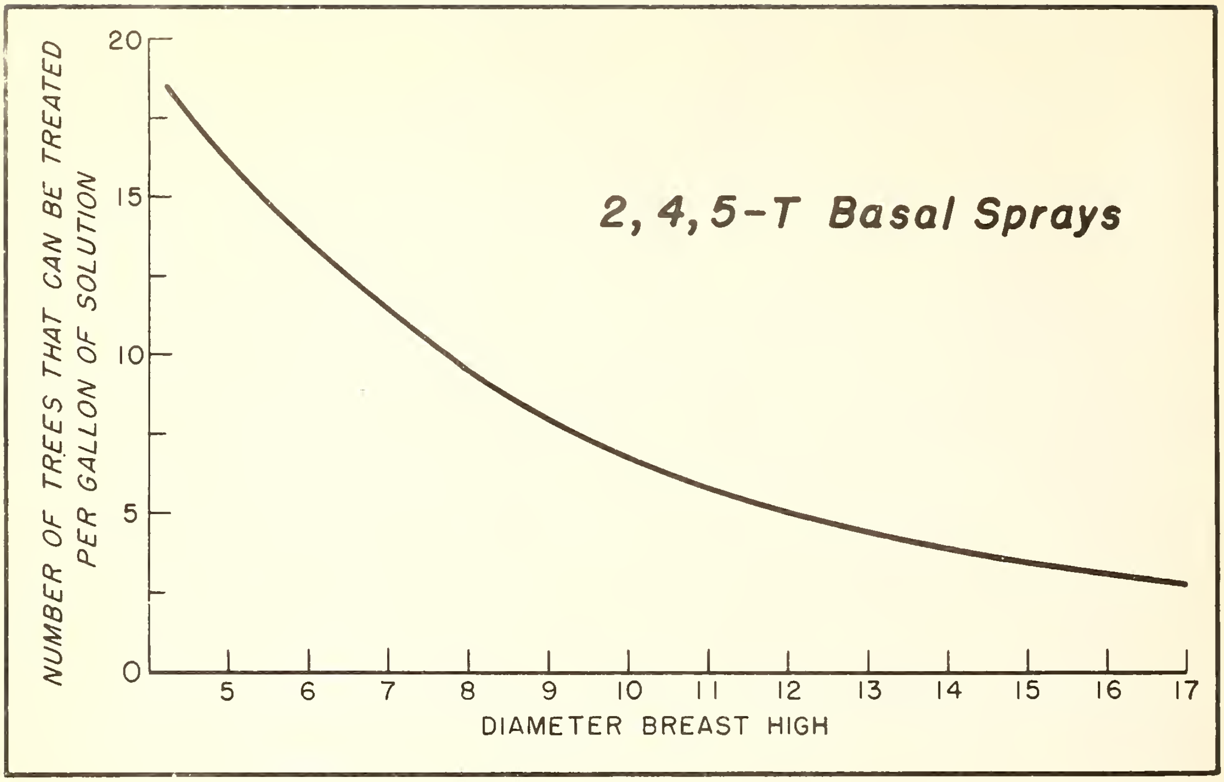

Figure 8.--Basal sprays use about three times more chemical solution than frills. One gallon of basal spray solution will treat about 14 trees 6 inches d.b.h. and only about three trees 17 inches.

that it costs about 5 cents, for chemicals alone, to kill a 6-inch tree, and about 21 cents for a 15-inch tree. For frilling, the chemicals cost a little more than 1/2 cent per 6-inch tree and about 1-1/2 cents per 15-inch tree. Thus the chemical cost of basal sprays is 10 to 15 times the cost of frills.

It is true that the labor cost of basal sprays is less than that required for frills. For example, in one test we found that the labor of chopping a frill and pouring the solution into a tree 10 inches d.b.h. consumed 1.44 man-minutes, or at 75 cents per hour, a labor cost

of 1.8 cents per tree. It took 0.96 man-minutes or 1.2 cents worth of labor to basal spray the same tree. Spraying is also easier and safer work than chopping frills.

Possibilities for lowering the cost of basal spraying by reducing the dosage or the concentration of 2,4,5-T are limited. For certain species, hornbeam, and waxmyrtle, 1 percent (acid by weight) appears to be sufficient. However, for the woods-run of species, anything less than 3 percent gave erratic results. Still another way would be to use a cheaper diluent than fuel oil. Thus far, water carriers with added penetrants have given only indifferent results. Yet we believe that further research will find ways to reduce the costs of basal sprays.

There is a good possibility that basal sprays can be used economically to poison trees too small to frill or notch. We have had excellent kill of trees averaging about 1 inch d.b.h. at a cost of less than 1/2 cent per tree for chemicals and labor. This method is also being used more and more to control brush along rights-of-way, in lieu of foliage sprays and especially for species resistant to foliage sprays.

TIME OF YEAR FOR POISONING

It is usually preferred, in the Southeast, to carry on timber stand improvement programs during the fall, winter and early spring. Labor is more readily available and can work more efficiently in hardwood brush during those months. Foliage sprays, of course, must be applied during the growing season, but the other poisoning techniques can be done at any time of the year. While it is possible that poisoning during the growing season may be more effective or require less chemical, such savings will surely be offset by the advantages of fall to spring treatments. For this reason we have designed our research for dormant season application.

Both the frill and basal spray techniques, using 2,4,5-T, kill trees rather slowly. We have observed, however, that trees are killed

more quickly if treated just prior to spring leafing. Whether or not the speed of deadening is associated with more complete kill, is still to be determined.

SOME COMPARATIVE COSTS OF POISONING METHODS

In one test, small but precisely controlled, comparative costs were extracted for several different methods of deadening large trees. The usual tree species associated with loblolly pine were represented, ranging from 5 to 25 inches d.b.h. Treatments were made on half-acre plots selected so as to be almost identical in number of trees and basal area. Costs for the several treatments are given in table 2 below.

Table 2.--Relative costs of poisoning methods compared to girdling, and costs per 10-inch tree [1/]

Method	Relative cost	Labor	Per 10-inch tree		
			Labor	Chemical	Total
	Percent	Percent	Cents	Cents	Cents
Double-hack girdle	100	100	4.8	--	4.8
Ammate notches	190	25	1.8	5.3	7.1
2,4,5-T frill	71	60	1.8	1.2	3.0
2,4,5-T basal	278	10	1.3	10.4	11.7
2,4,5-T stump	245	10	0.9	7.9	8.8

1/ Only direct costs of labor and chemical are given; all other costs are excluded. Labor is at rate of 75¢ per hour, chemicals atcurrent cost to industrial consumer.

CHEMICALS AND PINE MANAGEMENT

Although this booklet deals principally with chemical techniques, the forest owner should remember that other methods and combinations are available. Examples of these are demonstrated on the Santee Experimental Forest, near Charleston, S. C., in loblolly pine with dense hardwood understories and cull hardwoods intermingled with the overwood. On one block the low brush was broken up with a tractor-drawn disk harrow just prior to the seedfall. Then the pine stand was cut to seed trees, and the residual cull hardwoods poisoned after logging. This area is under control and will regenerate to pine--at a direct cost of $6.12 per acre. Another block was placed under control by prescribed fire and large-cull poisoning, at a direct cost of $2.87 per acre. Still other blocks with low brush and no large culls are controlled by prescribed fire alone, or by disking. On some areas where fire or disking cannot be used because of the presence of pine reproduction, seedlings were released from the competition of heavy brush by cleaning or weeding with chemicals--at a cost of about 2 cents per released seedling.

The chemical techniques can be used to control--or, if desired, eradicate from the forest--all trees and shrubs of all species and sizes, even the pines. But not a single one will do the entire job, nor should the forester rely upon chemicals alone. Along with the other tools he commands, these chemical aids will permit the forester to solve specific problems of controlling weed species.

SUMMARY

The following suggestions are based on 5 years of experimentation in the flatwoods of South Carolina. This research is still in progress. Recommendations, therefore, are tentative and subject to revision.

Chemicals to use

2,4,5-T (the low-volatile esters of 2,4,5-Trichlorophenoxyacetic acid) is marketed as a liquid concentrate (usually containing the equivalent of 4 pounds of 2,4,5-T acid per gallon) and must be diluted for use. The diluent or the carrier may be either water or oil (such as kerosene, fuel oil, or diesel oil) depending upon the method used.

Ammate (trade name for ammonium sulfamate) is marketed and often used in the crystalline form. It may also be used in a water solution.

Both Ammate and 2,4,5-T are useful. Ammate is corrosive to metal and, while non-toxic, may cause skin irritation under prolonged contact. 2,4,5-T is neither corrosive, toxic, nor irritating. It kills vegetation more slowly than Ammate, but is often cheaper to use.

Methods of application

Foliage sprays.--Either Ammate or 2,4,5-T may be used as a water solution. This method is most useful for 1- or 2-year-old sprouts or brush up to 6 feet tall. All foliage must be sprayed to the point of runoff.

Notches or cups.--Crystalline Ammate may be placed in notches cut in the trunk at the base of the tree. The number of notches to be used equals one-half the diameter of the tree in inches at breast height. In each notch, place one rounded tablespoonful of Ammate (about 1 ounce).

Frills.--Either Ammate or 2,4,5-T, as a water solution may be poured into single-hack girdles or overlapping ax cuts encircling the tree at convenient chopping height.

Stumps.--An oil solution of 2,4,5-T may be sprayed to the point of runoff, on the tops and sides of freshly-cut stumps. Crystalline Ammate, at the rate of 1 tablespoonful per 2 inches of stump diameter, may be placed on stump tops.

Cornell tool.--High concentrations of Ammate in water solution are injected into the base of the tree. A single "jab" should be sufficient for stems 1 or 2 inches d.b.h.; larger trees require correspondingly more "jabs."

Basal sprays.--2,4,5-T in an oil solution is sprayed on a band of bark encircling the base of the tree. For stems under 2 inches d.b.h., the band should be about 12 inches wide; for larger stems, 24 inches wide.

Recommended concentration for various poisoning methods

Chemical and Method	Concentration or dosage [1/]
2,4,5-T foliage sprays	1 gallon 2,4,5-T to 200 gallons water
2,4,5-T frills	1 gallon 2,4,5-T to 50 gallons water
2,4,5-T basal sprays	1 gallon 2,4,5-T to 20 gallons oil
2,4,5-T stump sprays	1 gallon 2,4,5-T to 20 gallons oil
Ammate foliage sprays	1 pound Ammate to 1 gallon water
Ammate notches	1 tablespoon Ammate crystals per notch
Ammate frills	2 pounds Ammate to 1 gallon water
Ammate-Cornell tool	6 pounds Ammate to 1 gallon water
Ammate stumps	1 tablespoon Ammate crystals per 2 inches of stump diameter

[1/] Concentrations of 2,4,5-T are based on commercial products of low-volatile 2,4,5-T esters containing the equivalent of 4 pounds of 2,4,5-T acid per gallon of product.

Alternative methods of poisoning - by species and sizes

(ranked in order of efficiency)

Species	Brush (under 6 ft. tall)	Small trees (1 to 4 in. d.b.h.)	Large trees (over 4 in. d.b.h.)
Sweetgum and blackgum	2,4,5-T foliage Ammate foliage 2,4,5-T basal	Ammate notches 2,4,5-T basal Ammate-Cornell 2,4,5-T stump Ammate stump	Ammate notches Ammate frill 2,4,5-T frill 2,4,5-T stump Ammate stump
White oaks and red oaks	Ammate foliage 2,4,5-T basal	Ammate notches 2,4,5-T basal Ammate-Cornell Ammate stump 2,4,5-T stump	2,4,5-T frill Ammate frill Ammate notches Ammate stump 2,4,5-T stump
Hickories and beech	2,4,5-T basal Ammate foliage	2,4,5-T basal Ammate notches Ammate-Cornell 2,4,5-T stump	2,4,5-T basal 2,4,5-T frill Ammate notches 2,4,5-T stump
Myrtle	2,4,5-T basal Ammate foliage 2,4,5-T foliage	2,4,5-T basal Ammate notches Ammate-Cornell 2,4,5-T stump Ammate stump	2,4,5-T basal Ammate notches 2,4,5-T stump Ammate stump

Season to treat

Foliage sprays must be applied during the growing season, any time between full leafing and late summer. All other poisoning techniques can be carried out at any time of the year, but are more easily applied during the dormant season.

Commercial products available [1]

These chemicals may be purchased from local distributors of the following manufacturers:

Dow Chemical Company markets the propylene glycol butyl ether ester of 2,4,5-T as "Esteron 245."

American Chemical Paint Company markets the butoxy ethanol ester of 2,4,5-T as "Weedone 2,4,5-T."

Du Pont Chemical Company manufactures "Ammate" and also distributes the propylene glycol butyl ether ester of 2,4,5-T as "Du Pont 245T Ester Brush Killer (low volatile)."

A satisfactory water-soluble dye used for frilling solutions is: "Du Pont Wood Stain Scarlet Conc. NS," mixed at the rate of 1 pound to 200 gallons of solution.

For stump sprays, an oil-soluble dye is available from Ciba Company, as "Oil Red CY," mixed at the rate of 1 pound to 160 gallons of solution.

1/ The list of products is presented for the convenience of users; the completeness of the list cannot be guaranteed. Listing does not imply warranty of the standard of the product to the exclusion of other products which may also be suitable.

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